Cryogenic Fracture Toughness Evaluation of an Investment Cast Aluminum-Beryllium Alloy for Structural Applications

National Space and Missile Materials Symposium

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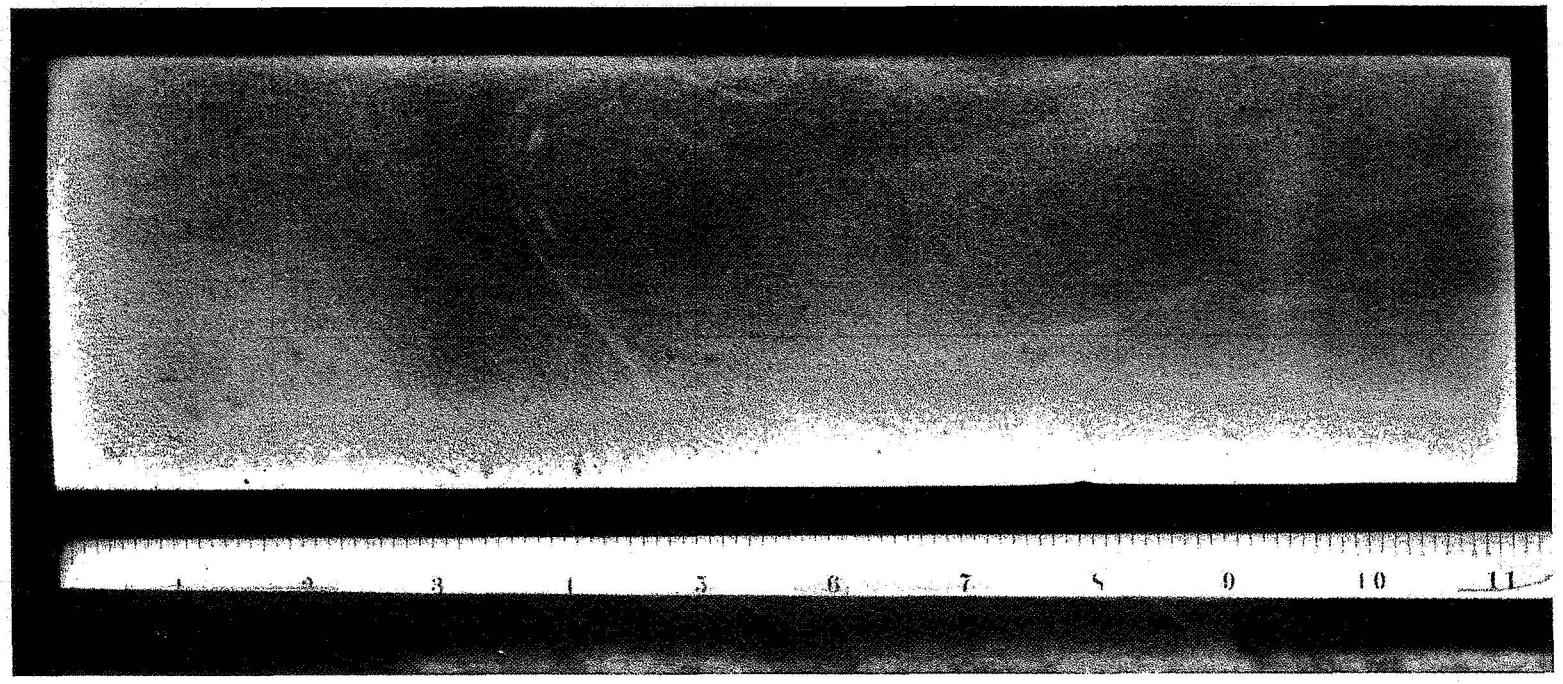
Introduction

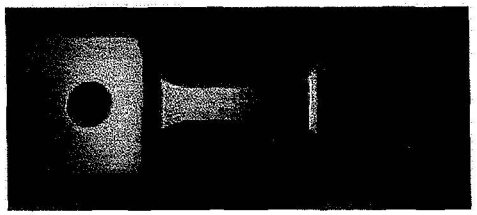
- Material – Investment Cast Beralcast 363
  - 63% beryllium
  - 32% aluminum
  - Balance – Ag, Co, Ge, Fe
- Processing – Starmet Corporation
  - PRS-001, Rev 11
  - Two Heat Lots: 12 plates ≈ 3" x 12" x 0.25"
  - Hot Isostatic Press at MSFC (15 ksi at 1000F for 145 minutes)
- Characteristics
  - High Specific Strength
  - High Stiffness
  - Low Coefficient of Thermal Expansion
  - Neutron Absorber

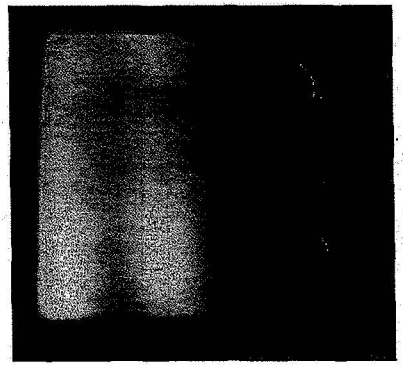
Inspection

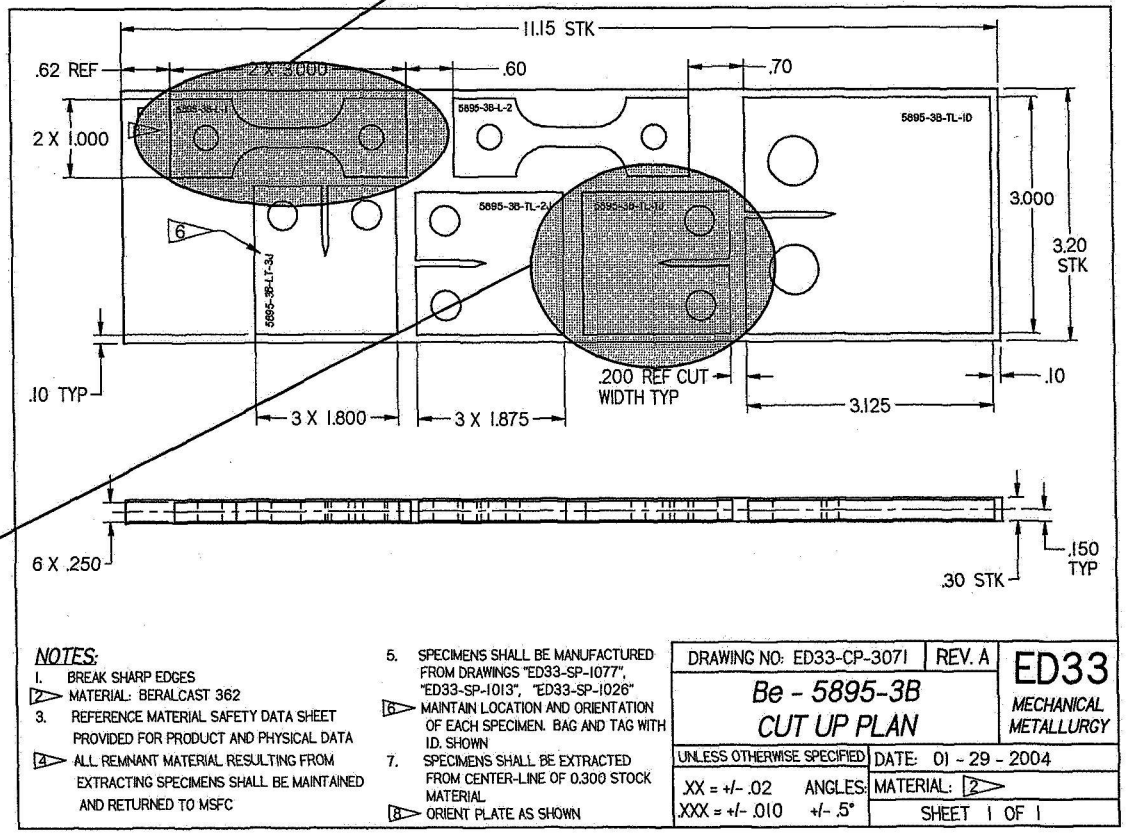


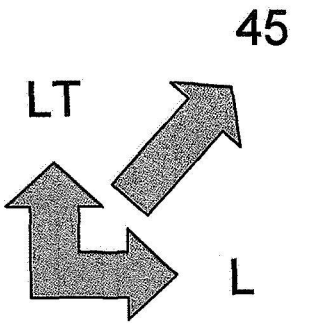
Radiography on as-received plates
No anomalous indications

Test Sample Configuration









ORIENTATION

Tensile Testing

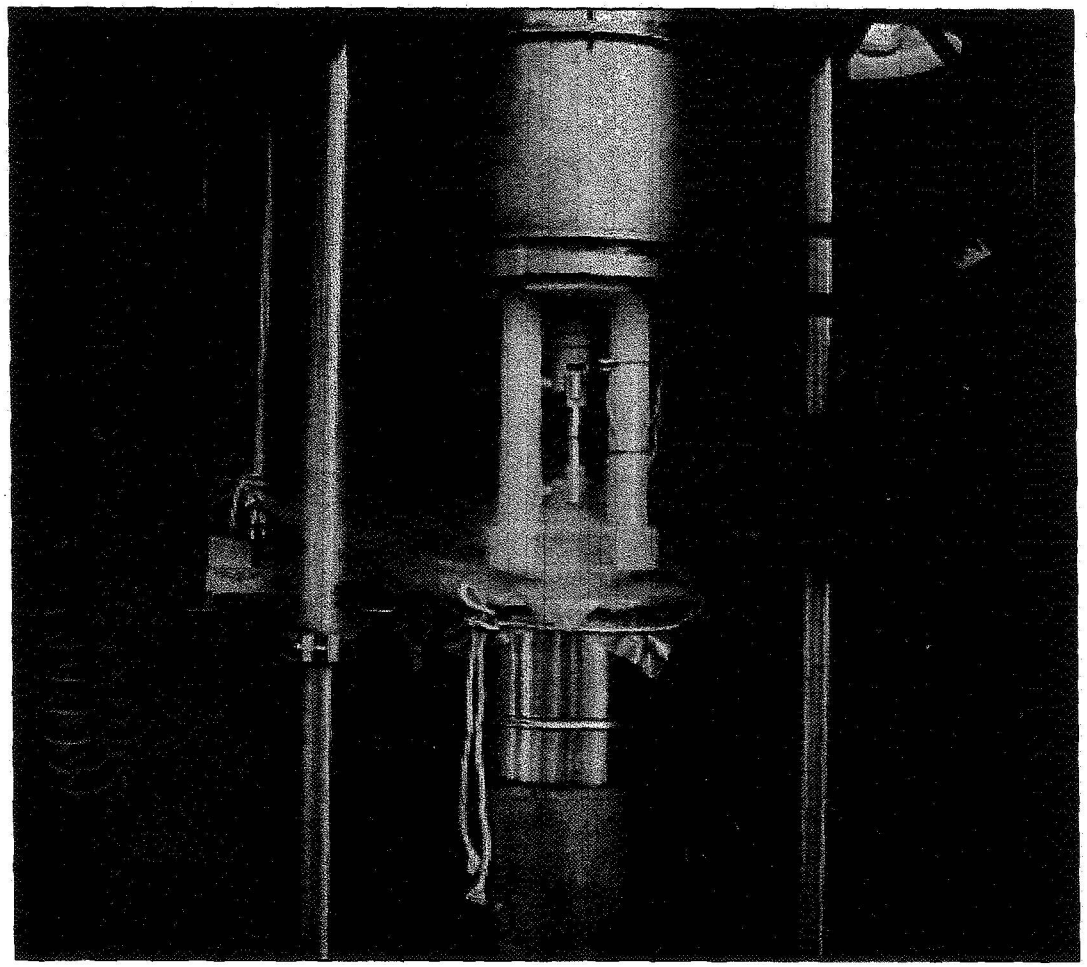
70 F (lab air)
-100 F (GN_2)
-320 F (LN_2)
-423 F (LH_2)

Tension

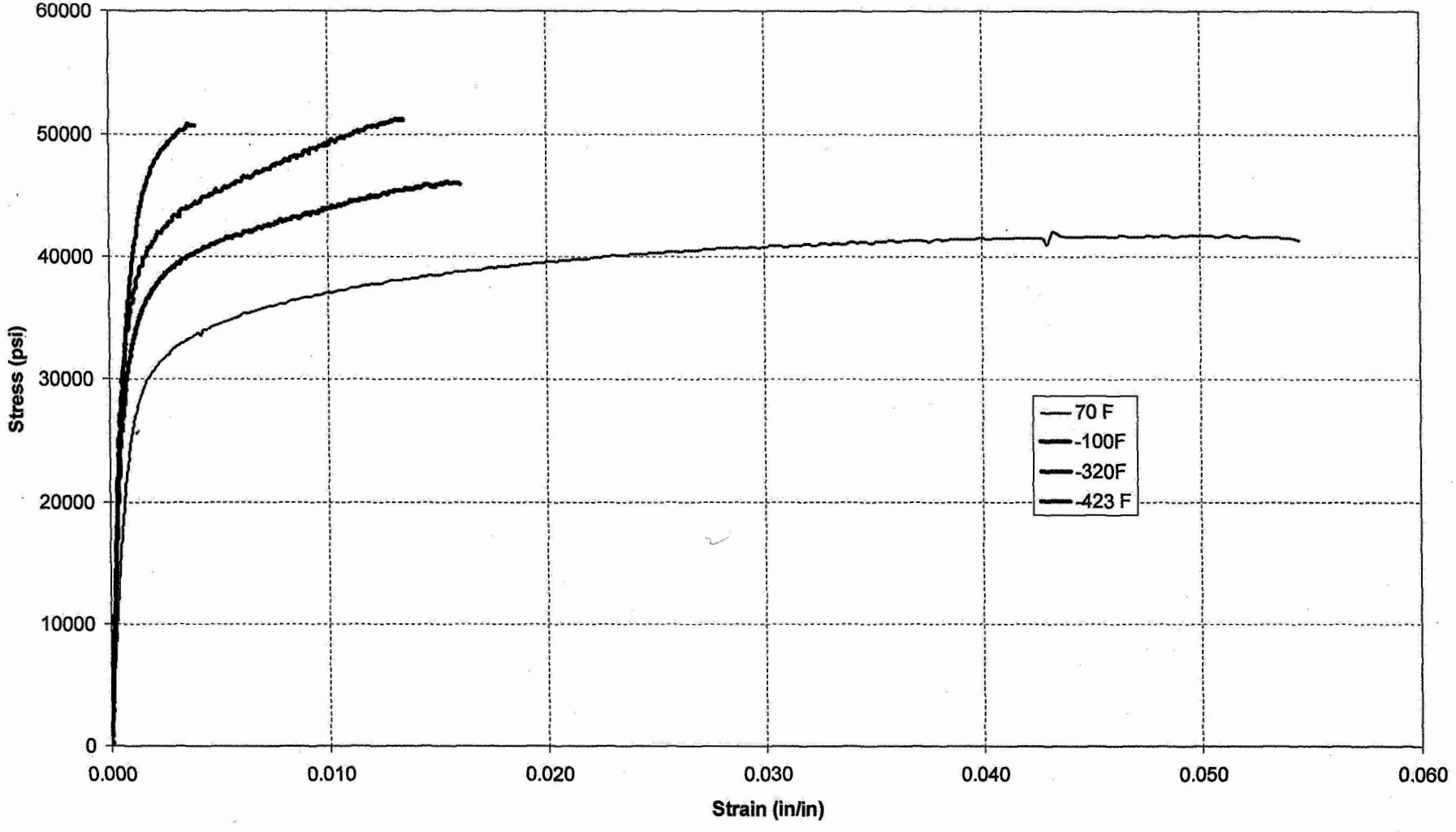
Limited data set:

At room temperature:
9 longitudinal transverse samples

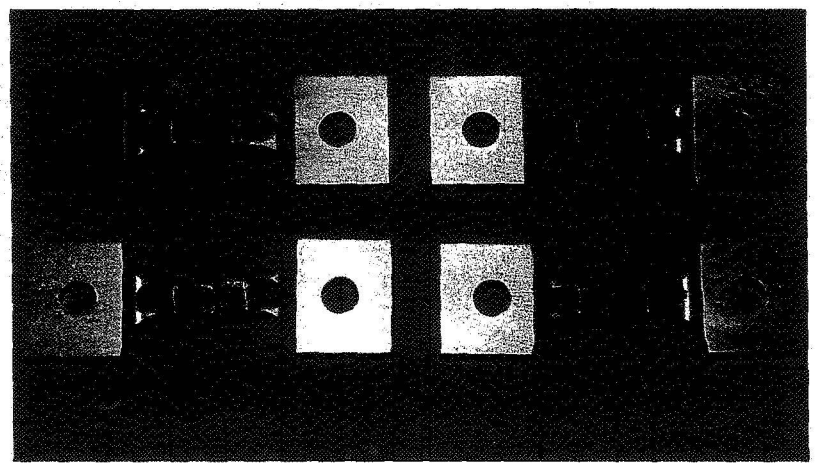
At cryogenic temperatures:
2 longitudinal samples
1 longitudinal transverse sample
1 45 sample



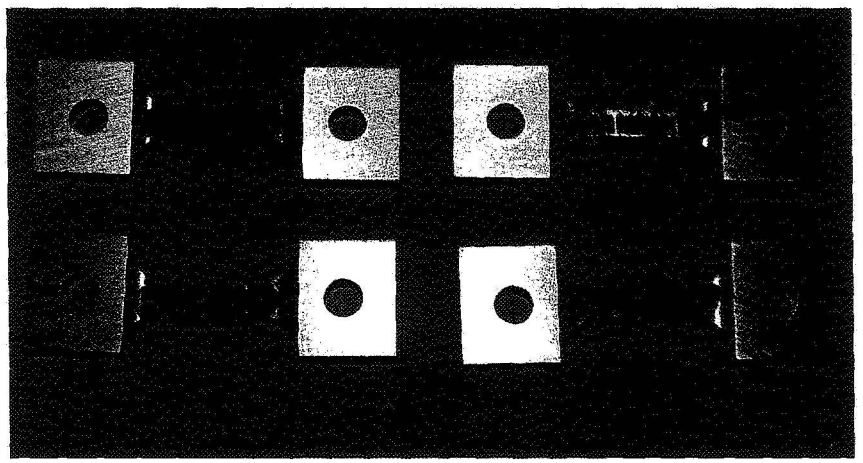
Typical Stress-Strain Behavior as a Function of Test Temperature



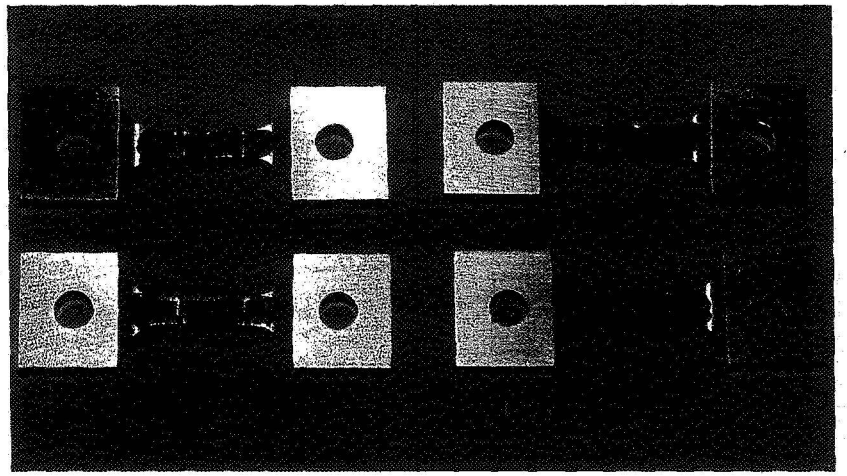
Typical Tension Test Failure Patterns



-100 F

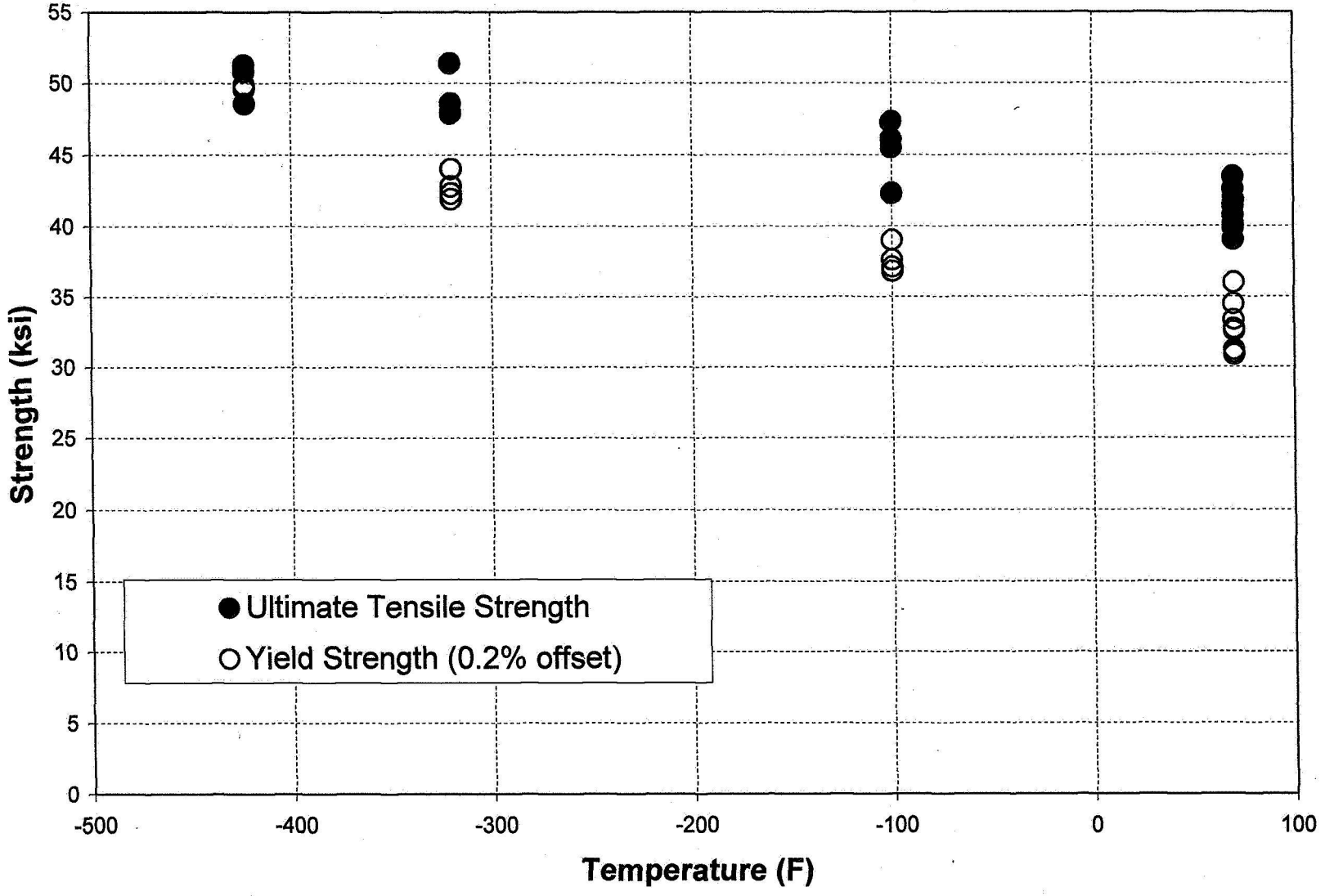


-320 F



-423 F

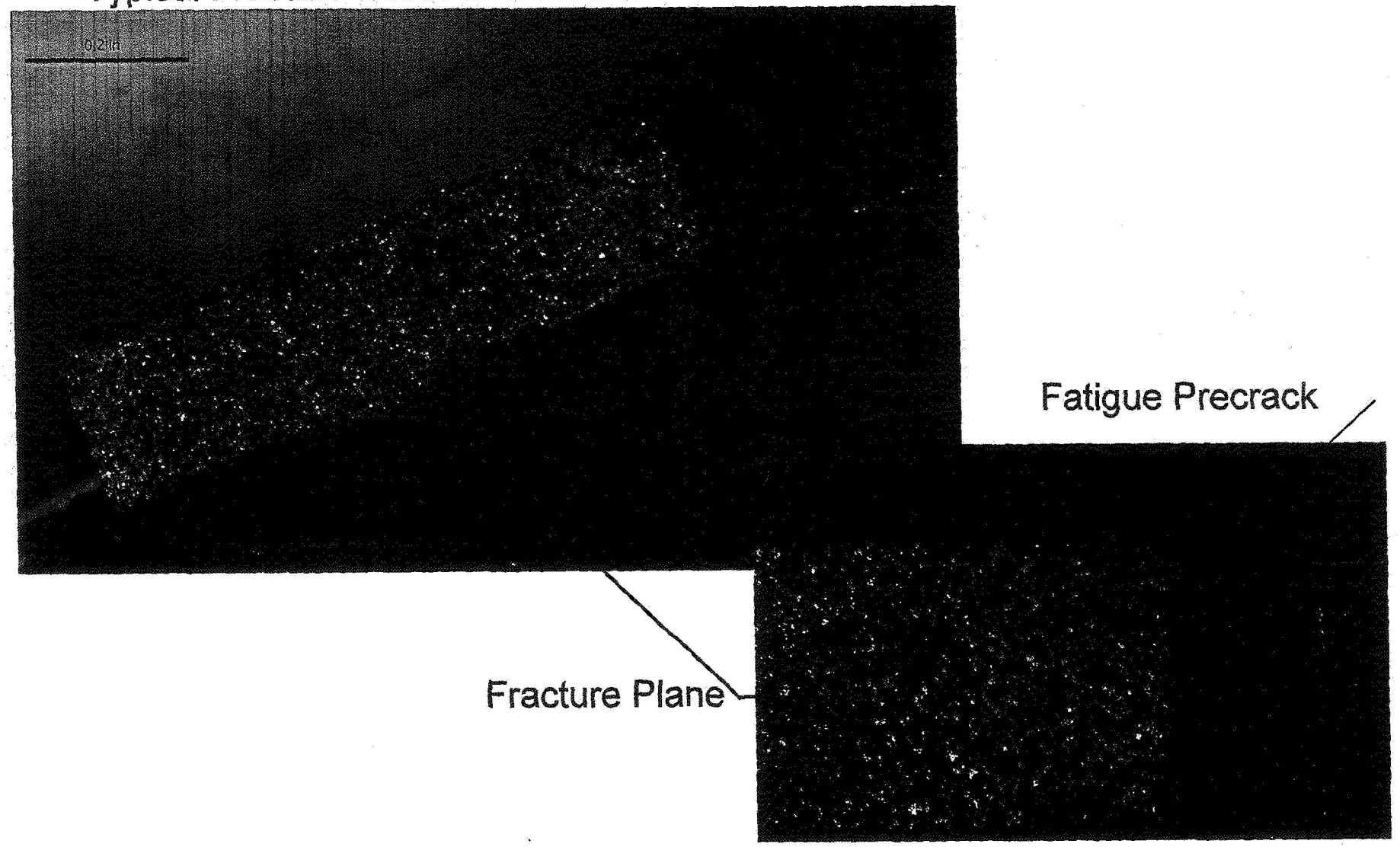
Strength Versus Temperature
L, LT, and 45 Orientations



Tensile Test Observations

- Flat fracture surfaces, with no discernable necking.
- Yield strengths increase with decrease in temperature.
- Ultimate strengths increase with decrease in temperature, plateau at -320 F.
- Increase in elastic modulus with temperature.
- Decrease in elongation with temperature.
- At a given temperature, no discernable difference between L, LT and 45 strengths.

Typical Fracture Test Failure Surface



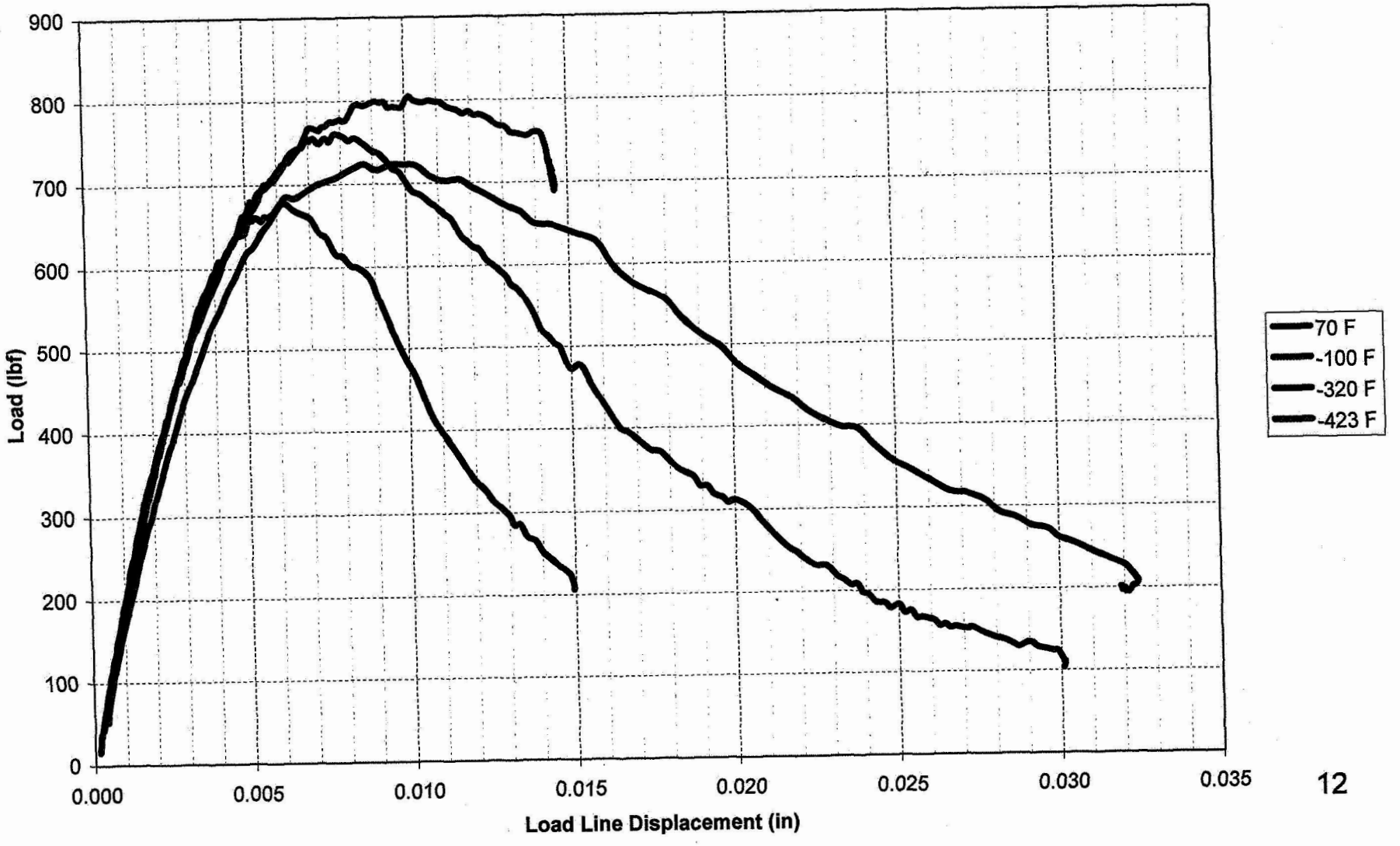
Fracture Toughness Testing

Summary of Fracture Test Orientation and Temperatures					
		TEMPERATURE			
		70	-100	-320	-423
ORIENTATION	T-L	1	1	1	1
	L-T		2	1	1
	45				1

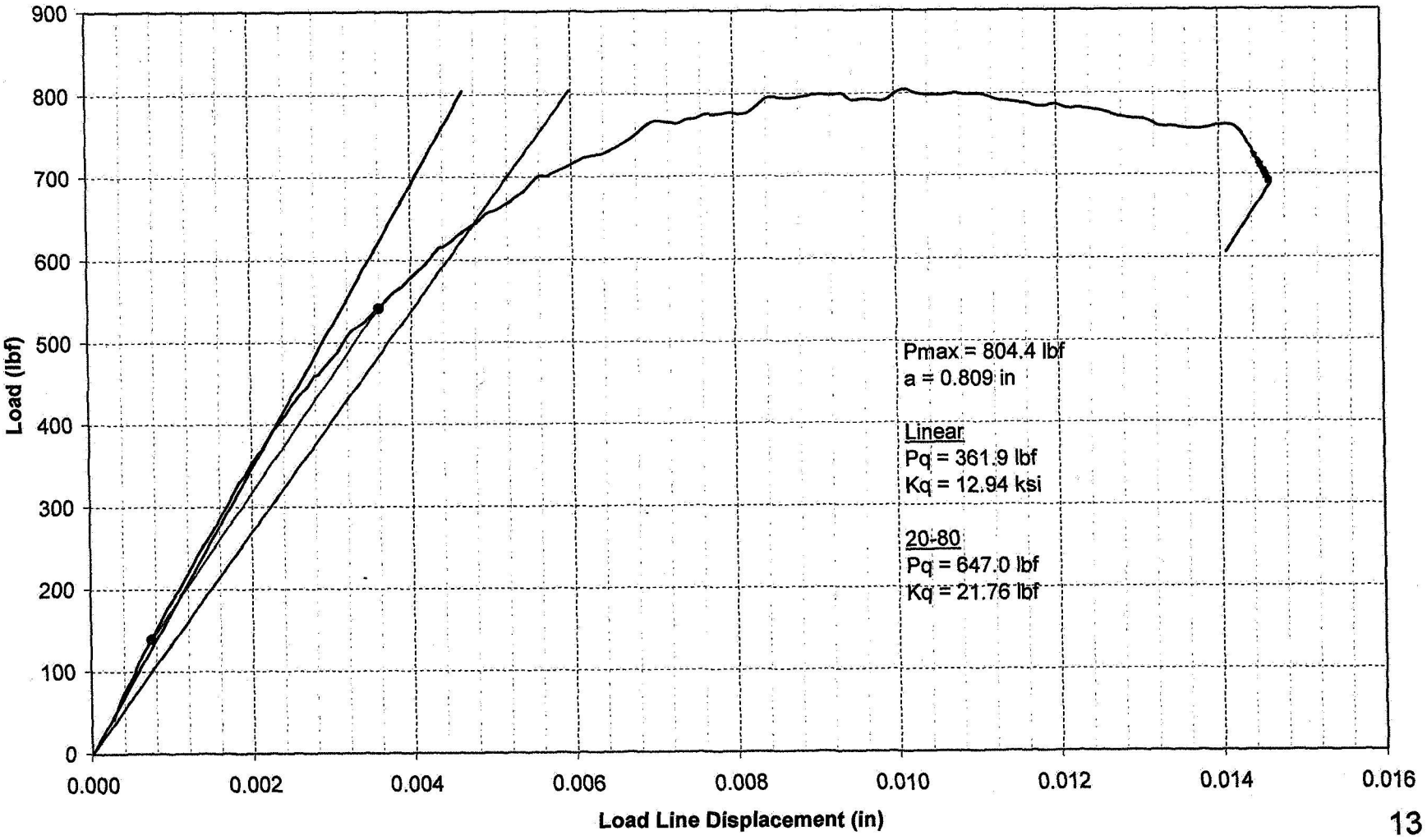
Fracture Toughness (ksi√in) as a Function of Temperature and Orientation					
		TEMPERATURE (° F)			
		70	-100	-320	-423
ORIENTATION	T-L	12.9	12.5	12.0	14.7
	L-T		12.6, 11.1	13.6	12.7
	45				11.9

Fracture Toughness (ksi√in) as a Function of Temperature and Orientation Appendix 8. Special Requirements for the Testing of Beryllium					
		TEMPERATURE (° F)			
		70	-100	-320	-423
ORIENTATION	T-L	21.8	23.9	23.6	21.6
	L-T		23.2, 21.9	21.6	21.2
	45				21.6

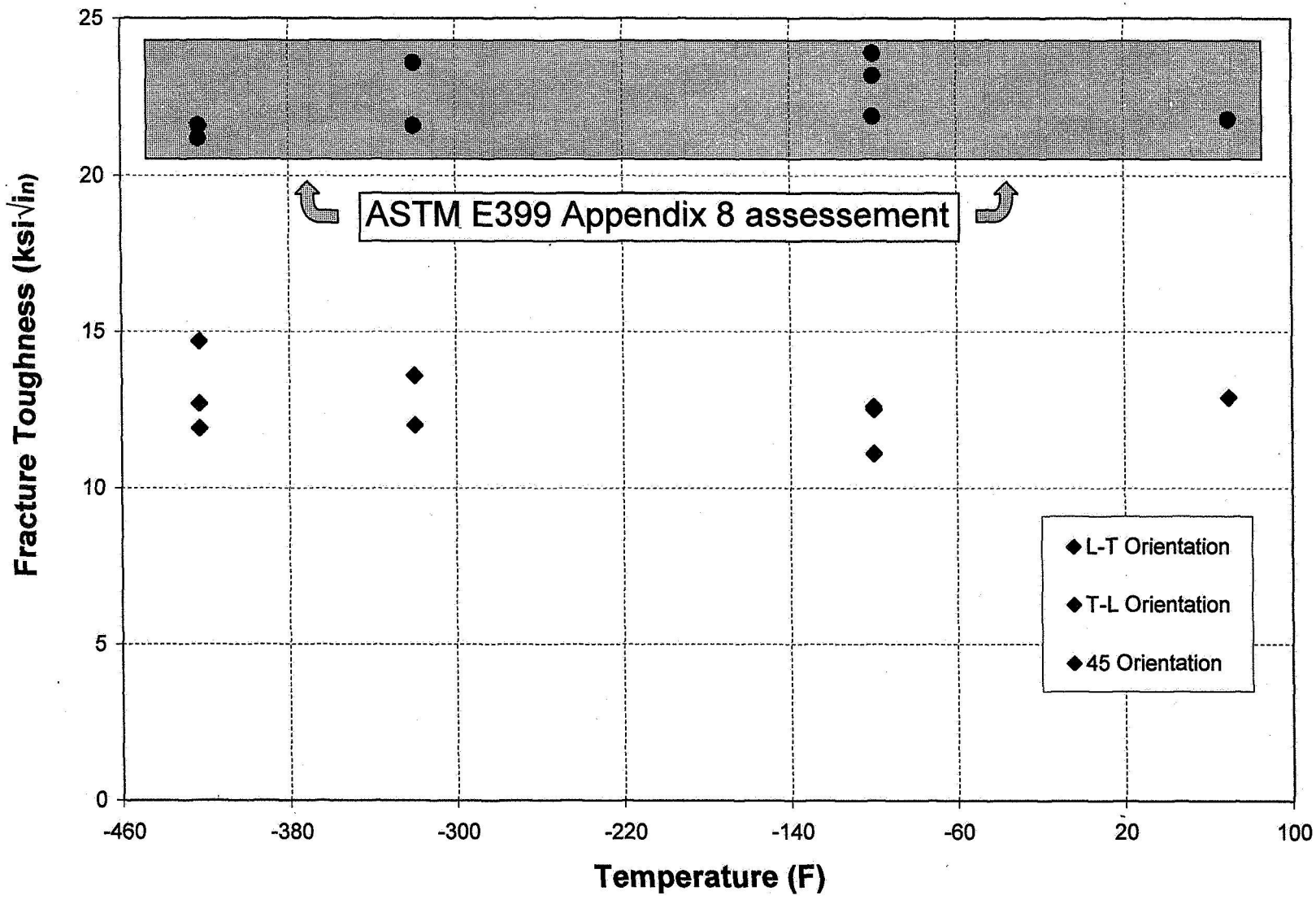
Load - Displacement Curves as Function of Temperature

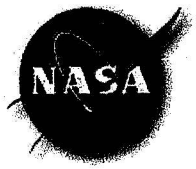


Sample 51236
RT, T-L Orientation



Fracture Toughness as a Function of Temperature and Orientation

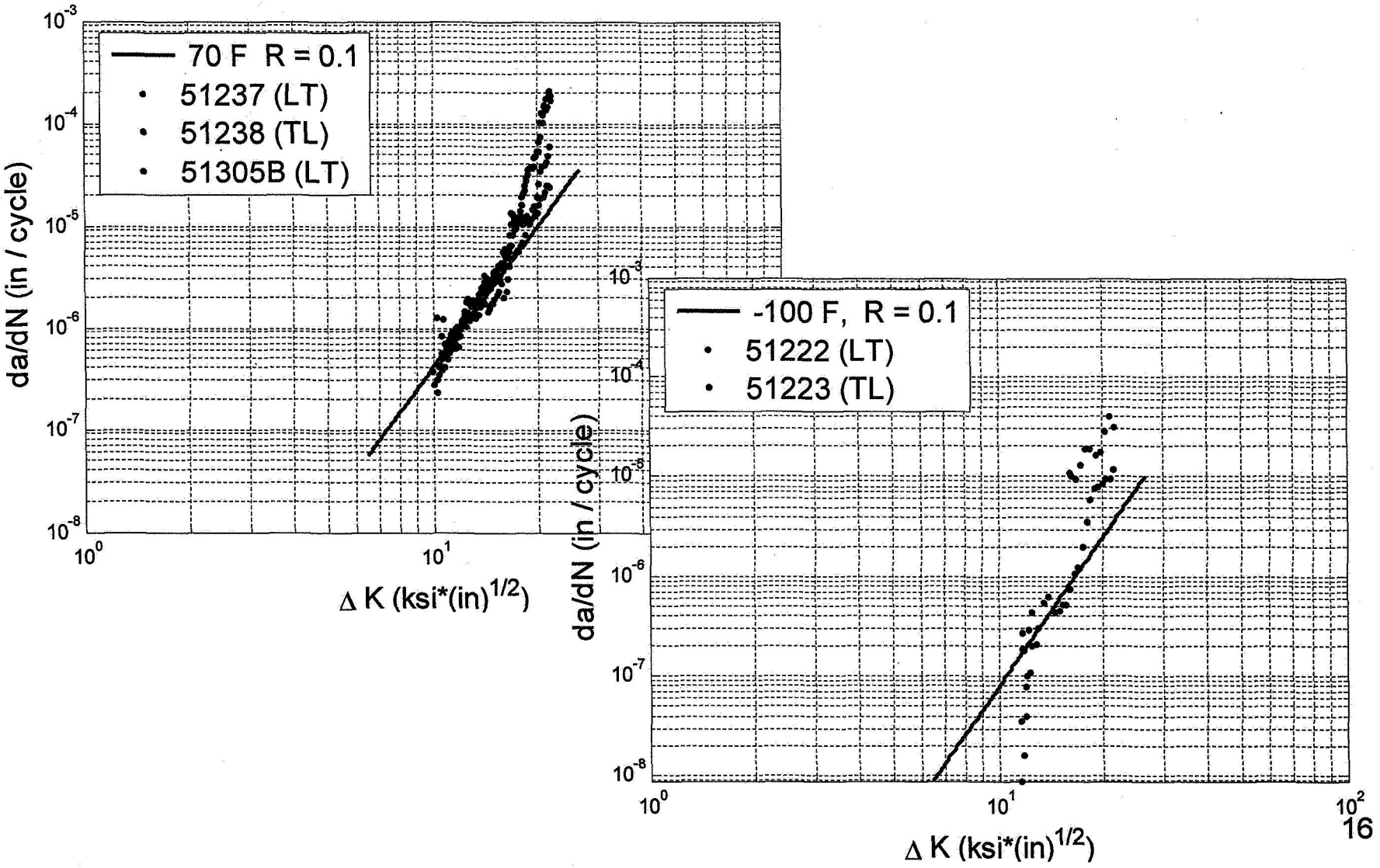


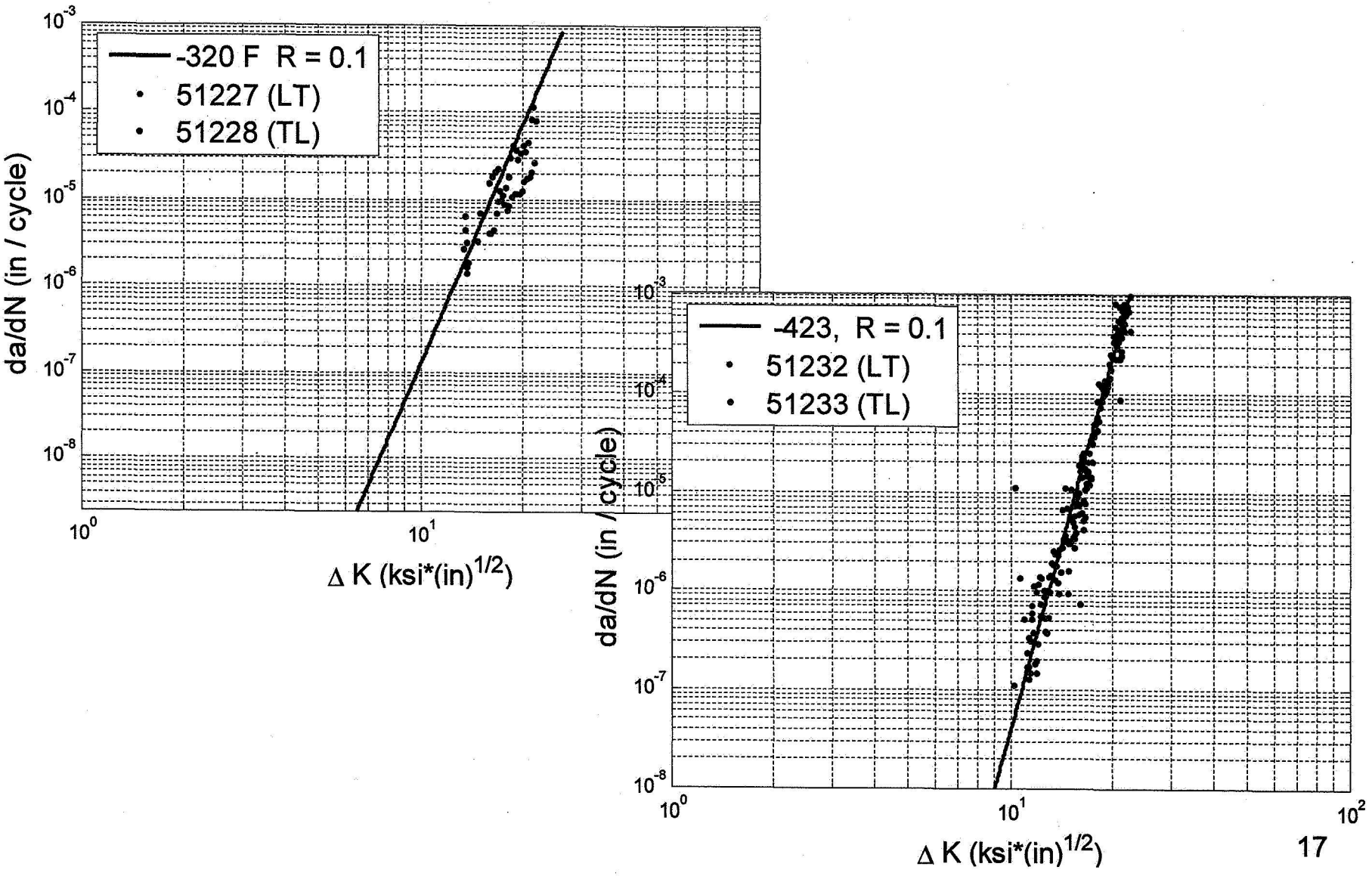


Fracture Test Observations

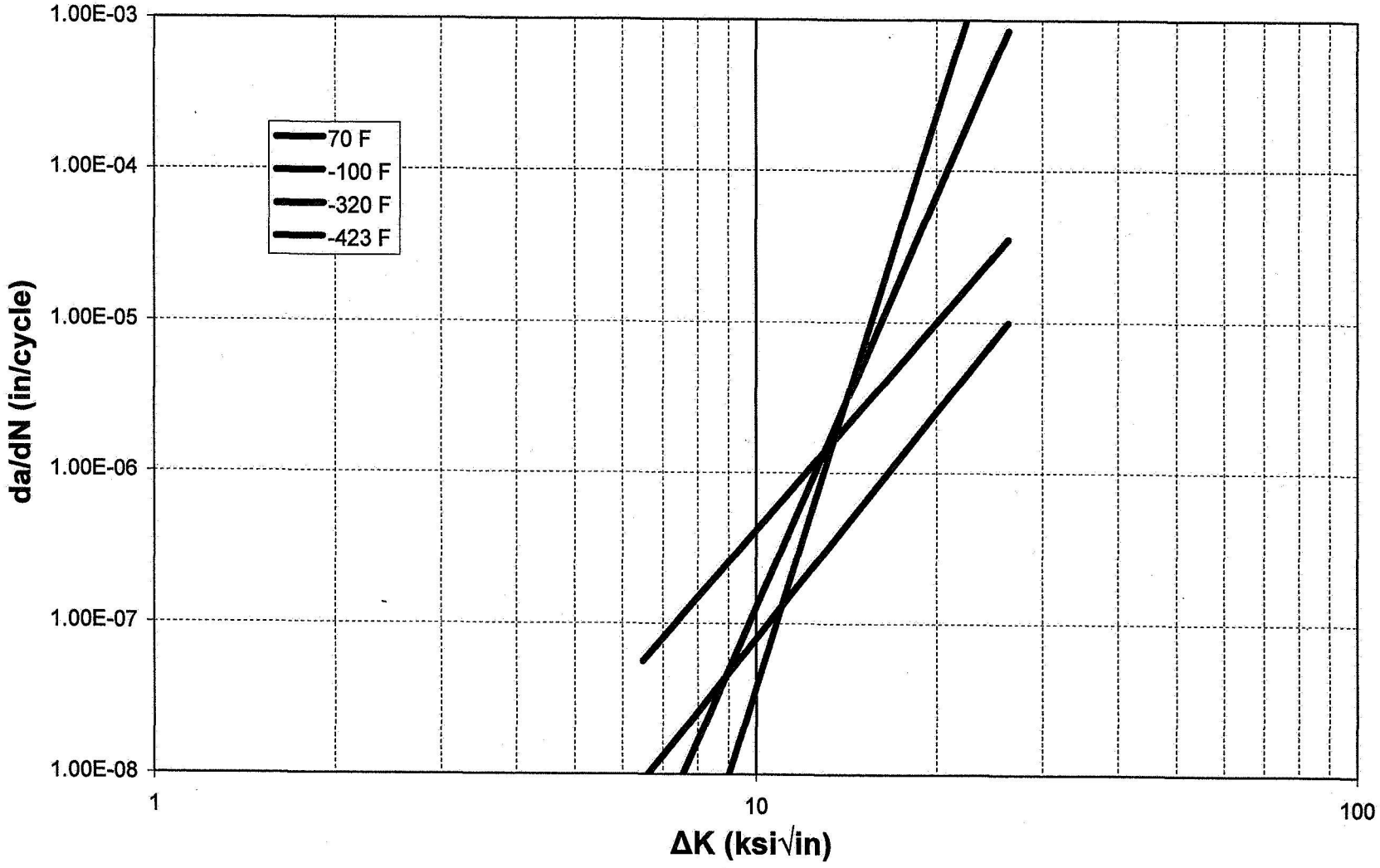
- Flat fracture surfaces, with no discernable necking.
- Type I fracture.
- No discernable changes in toughness values with temperature.
- At a given temperature, no discernable difference between L, LT and 45 toughness values.
- Disparity between E399 linear offset toughness and "special requirements" toughness
  - Subcritical crack growth assessment
  - Thickness requirement
  - Hot-pressed beryllium

Crack Growth Rate Testing




-320 F R = 0.1
51227 (LT)
51228 (TL)
da/dN (in / cycle)
Δ K (ksi*(in)^1/2)
-423, R = 0.1
51232 (LT)
51233 (TL)
da/dN (in / cycle)
Δ K (ksi*(in)^1/2)

Trends in Paris Region Crack Growth Behavior as a Function of Temperature



Summary of da/dN Test Orientation and Temperatures (R= 0.1)					
		TEMPERATURE			
		70	-100	-320	-423
ORIENTATION	T-L	1	1	1	1
	L-T	1	1	1	1

Slope in Paris Region as a Function of Temperature (R= 0.1)			
TEMPERATURE (° F)			
70	-100	-320	-423
4.6	5.0	9.1	12.6

RECOMMENDATIONS

- Evaluate J-R behavior of material to assess sub-critical crack growth behavior.
- Assume fracture toughness of 12.0 ksi$\sqrt{in}$
- Use caution when using material below -100 F in fracture critical applications.
  - Low elongation
  - Steep da/dN curve